rains; 11 storms causing insignificant losses by wind compared with the great benefits to crops and municipal water supplies.

The historic storms of August 8, 1899, and September 13, 1928 (known respectively as San Ciriaco and San Felipe) occurred at the beginning and at the end of the 30-year period. The storms of secondary destructive force (class B) occurred as follows: July, 1926; August, 1909, 1915, 1916; September, 1906, 1910.

An inspection of the accompanying chart (fig. 2) showing the time distribution of hurricanes of Porto Rico will show that the 12 "beneficial" hurricanes (class C) comprise 60 per cent of the total number of cyclonic storms recorded in the past 30 years; that 6, or 30 per cent (class B) seriously affected only certain portions of the island and that 2, or 10 per cent (class A) brought not only general destruction to crops and homes, but involved heavy loss of life.

Combining all classes we have 10 per cent of the storms occurring in July, 30 per cent in August, 55 per cent in September, and 5 per cent in October. The period of 30 years is too short to give these percentages a dependable value, they may however be regarded as rough measures of frequency and intensity for Porto Rico.

We may disregard class C as a cause for alarm. Considering only classes A and B: (*a*) There has been no single year with more than one storm; (*b*) the 6-year period 1900 to 1905, the 4-year period 1911 to 1914, and the 9-year period 1917 to 1925 were without storms of even moderate violence.

THE WEST COAST ATMOSPHERIC FAULT[1]

By EDWARD H. BOWIE

[Weather Bureau, San Francisco, Calif., July 29, 1929]

Meteorologists have heard often and read much in recent years of surfaces of discontinuity in the earth's atmosphere. The Bjerknes school of meteorology has done much to bring them to the attention of meteorologists and to define their significance in the causation of our major atmospheric phenomena.

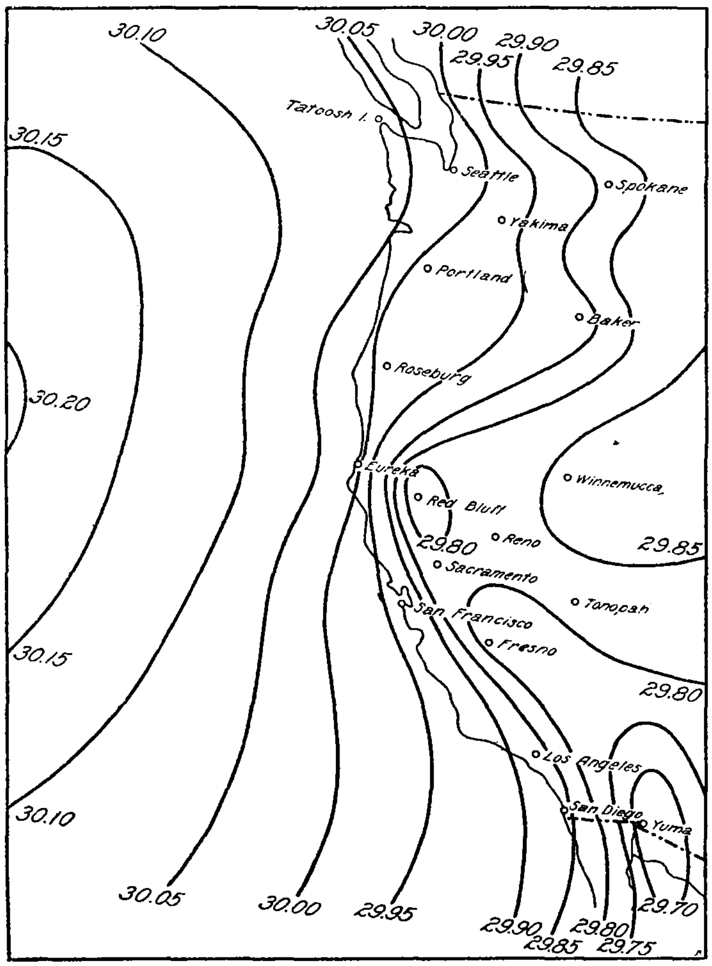

FIGURE 1.—Average sea-level pressure at 5 p. m. third decade of July

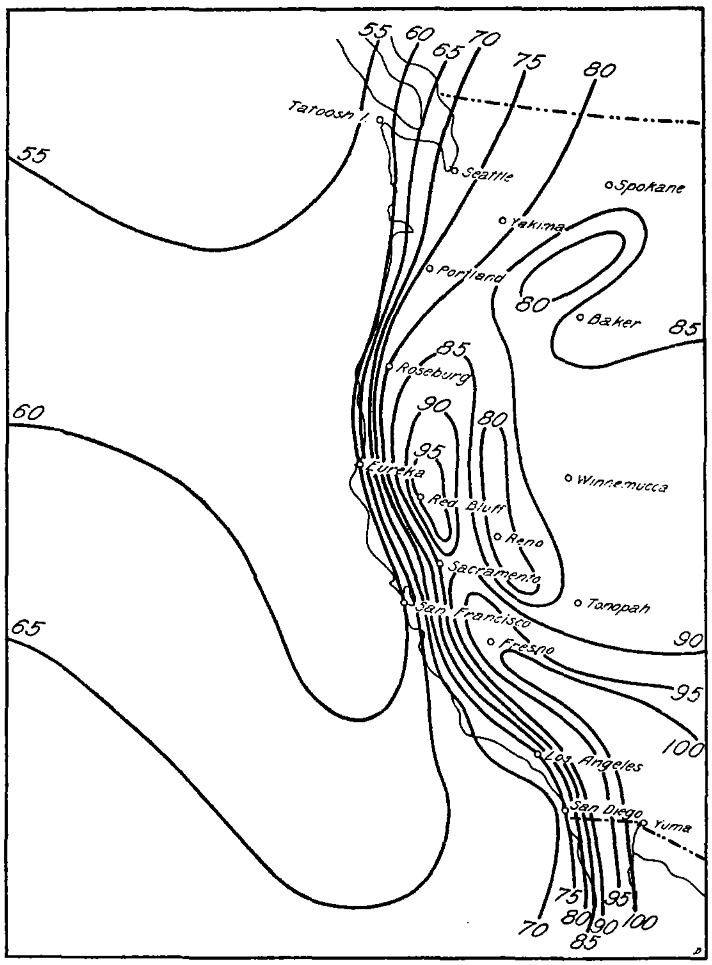

FIGURE 2.—Average air temperature at 5. p. m. third decade of July

The Bjerknes school of meteorologists asserts that all of our cyclones occur on the discontinuities that intersect the earth's surface. Of these there are three major ones—(1) that separating the lower stratum, the troposphere, from the upper stratum, the stratosphere; (2) the boundary between the trades and the antitrades of the Tropics; and (3) the so-called "polar front" of the middle latitudes.

To these might well be added that seeming surface of discontinuity separating the trade-wind system of the Northern Hemisphere and that of the Southern Hemisphere. This one undergoes large variations in

[1] Presented before the meeting of the American Meteorological Society at Berkeley, Calif., June, 1929.

definition and geographical location, but it is confined to those regions of the doldrums that are described as centers of maximum frequency of occurrence of tropical cyclones. One of these is located on the Atlantic in the vicinity of the Cape Verde Islands, a second in the western part of the Caribbean Sea, and a third off the west coast of Central America and Mexico. Yet another may be found extending from the vicinity of Guam westward to the Philippine Islands, and still another over the Indian Ocean. No doubt the surfaces of discontinuity that intersect the surface on which the atmosphere rests are breeding places of cyclonic and other disturbances, but it does not necessarily follow that all such that intersect the earth's surface are breeding places of cyclones. Nevertheless, they are all places where contrasts in temperature, humidity, pressure, and wind direction and velocity, both in the horizontal and the vertical, are found.

These surfaces of discontinuity may be likened to atmospheric faults. They are counterparts, in a sense, of geological faults. Thus, if we bring together masses of polar and tropical air, these air strata fail to fit just as would be the case were two geological specimens from different parts of a stratified rock placed side by side. The reference to a surface of discontinuity as an atmospheric fault was, I believe, first made by Dr. G. C. Simpson, director of the British Meteorological Office, in an address on The New Ideas in Meteorology before the British Association, Section A, Southampton, 1925.

I assume that few of us realize that one of the most interesting of meteorological situations in respect to surfaces of discontinuity exists along our western coast. I have referred to this in the title of this paper as The West Coast Atmospheric Fault. It is notably defined in our warm summer months. The two masses of air involved in its formation are (a) the hot, dry air of the interior of the Far West and (b) the cold, humid air of the waters off our western coast. That this surface of discontinuity is a real one is wholly demonstrable. It is not always in evidence, but once having been obliterated it re-forms very quickly. Moreover, this surface of discontinuity, or atmospheric fault, after having once formed, not infrequently advances eastward and while advancing produces within it many of our cyclones that are first observed, in the summer season in particular, over our far Western States.

If you will refer to the daily weather map as issued by the San Francisco office of the Weather Bureau, there will be found occasions when areas of high barometric pressure pass inland from the Pacific Ocean by way of Washington, Oregon, and British Columbia and bring about uniform but high barometric pressure over our Northwestern States, the western Canadian Provinces, the northeast Pacific Ocean. At such times there is also more or less uniformity in temperature of the surface air over these parts of our continent and the waters of the Pacific Ocean adjacent thereto. At the same time the barometer remains low over the Gulf of California, and the upper air winds to considerable heights along the coast are from the north. Subsequently the air that has drifted on to the continent from the ocean has its temperature raised very sharply and rapidly by the radiation of heat to it from the earth's surface, and very quickly thereafter a marked temperature gradient is established between the ocean and the land. As this marked temperature gradient is established, the air pressure falls and the surface and upper air winds change their directions and speed. At such times the center of low barometer over the Gulf of California remains fixed in position, but to the north and northwest of it the barometer falls steadily and progressively even as far north as British Columbia. When the latter area (British Columbia) is

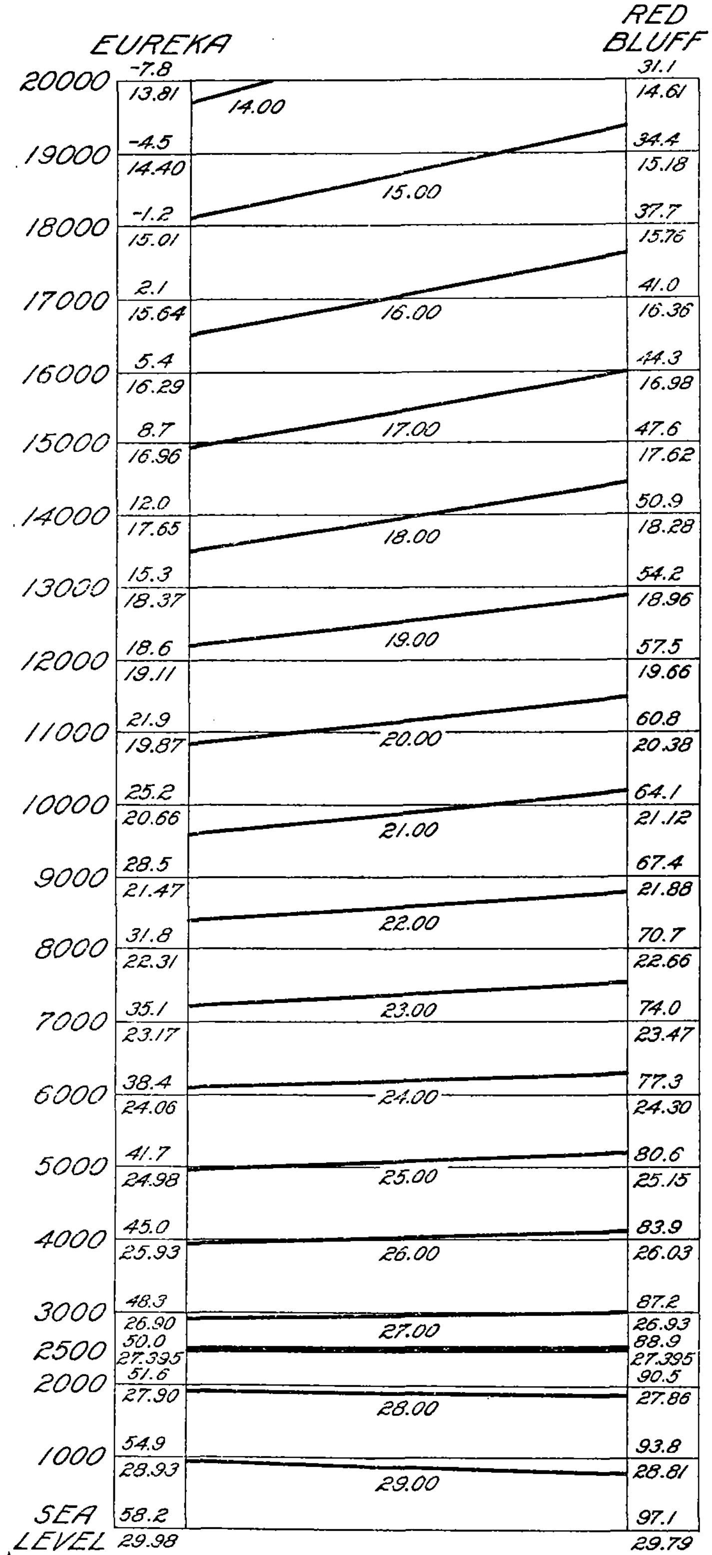

Figure 3.—Changes in pressure with elevation above Red Bluff and Eureka, Calif. respectively, due to surface temperature at the two places

involved in the rapidly rising temperature and falling barometric pressure, the meteorologist realizes that the fault has been accomplished the full length of the coast under consideration and that very quickly thereafter there will be a marked indraft of cool air from the waters off the coast, a corresponding fall in temperature over the interior, and the beginning of the eastward movement of the atmospheric fault itself. Due to the peculiar atmospheric conditions on the west coast the formation and eastward movement of this fault is not attended by the formation of cyclones except in the far north, where more than likely, one will form, its center first appearing over British Columbia or Alberta, Canada. The completion of the fault and its eastward movement are announced, as stated before, by the indraft of cool air, the incoming of sea fog, and a complete change in the régime that existed prior to and during the time when the fault was in process of formation.

To make clear that which I have brought to your attention, I am showing you charts and graphs. The first of these (fig. 1), gives the average distribution of air temperature as of 5 p. m. in the third decade of July in the far western States. The second (fig. 2) shows the distribution of sea-level pressure for the same time of the year. The third (fig. 3) shows the changing barometric situation determined by standard method that two observers would encounter if they were to ascend vertically over Red Bluff and Eureka, respectively. The observer rising from Red Bluff would ascend through air that is very much warmer than that through which the observer at Eureka would ascend. Consequently, the observer rising over Red Bluff would note that his barometer was falling relatively slowly with ascent as compared with the barometer carried by the observer who ascended over Eureka; also, the observer ascending over Red Bluff would note very quickly that his barometer for any given altitude above sea level beyond an altitude of 2,500 feet would stand higher than the Eureka observer's barometer. The sloping lines indicate the changing isobaric surfaces normally found between these two points under the conditions shown by graphs No. 1 and No. 2. Graph No. 1 brings this out very clearly and shows first that 2,500 feet above sea level is the altitude where the pressure between the coast and the interior as represented by Eureka and Red Bluff is the same, and secondly, that above that level the barometer over the interior stands higher in comparison with that over the ocean, despite the fact that at sea level the pressure at Eureka was the higher of the two. Consequently, we see that an entirely different régime of winds and pressure gradients is called for above this altitude, 2,500 feet, in comparison with the stratum below it.

Those of you who attended the meeting of the American Meteorological Society in Claremont in 1928 will recall that the question of a changed régime of pressure gradients and winds at high altitudes in comparison with lower altitudes was the subject of considerable discussion. It was then brought out that above the surface system of pressure distribution—namely, high barometric pressure over the coast and low barometric pressure in the interior—there was a complete reversal to high barometric pressure over the interior and low barometric pressure over the ocean. The charts of free-air winds at 4,000 meters of July 8, 9, and 10, 1928, show very clearly the transformation of the sea-level low-pressure system of the interior into a high-pressure system at 4,000 meters altitude. At this level the upper air winds show very definitely that the winds are anticyclonic. Here we have an example of the true Ferrel thermal cyclone.

The accurate forecasting of the changes in wind, weather, and temperature resulting from the formation and degradation of the west coast atmospheric fault calls for great skill on the part of the meteorologist. I am free to admit that I can not always determine from the available data exactly when the fault will begin and when it will be brought to an end. The forecasting of the changes associated with it is essentially different from the forecasting of changes commonly associated with the comings and goings of cyclones and anticyclones. We have made progress in that we know very definitely that we have an atmospheric fault that in our summer months is constantly forming or dissipating, and we shall soon learn its peculiarities and propensities and be able to forecast them.

THE GROWTH OF THE VESSEL WEATHER SERVICE OF THE NORTHEAST PACIFIC OCEAN[1]

551.509 (265.2)

By W. J. HUTCHISON

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Vessel weather reporting by radio was introduced in 1906. The present day reporting service is the outcome of an experiment conducted by the Weather Bureau in Washington, D. C., with the aid of 50 vessels whose captains agreed to take and transmit one meteorological observation daily at a time designated by the Weather Bureau. At a later date two observations were required and a fee of 50 cents paid for each observation taken and successfully transmitted. The results obtained from the extremely limited number of observations sent in were of little consequence and offered slight assistance to the weather forecasters. However, the original series of vessel reports was considered sufficient to prove that such a service could be developed to an untold degree of value in forecasting.

The service was not extended to the Pacific Ocean immediately and in 1907 only one vessel, the steamship *President* of the Pacific Steamship Co., was authorized to make reports. It is understood this vessel was the only one operating on the Pacific which carried wireless equipment at that early date. Lack of wireless apparatus on ships was one of the principal causes for the slow advance of vessel weather service on the Pacific.

Following the introductory years, the pioneers of this department of the weather work encountered many obstacles. Chiefly among them was the shortage of funds appropriated for observers' fees and radio tolls charged for transmission from ship to shore. Other stagnating influences contributing to the sluggish advance of the vessel service on the Pacific may be summarized as follows:

1. Difficulty in obtaining increased appropriations.
2. Inadequate increases were exhausted with but few new vessel stations established.
3. As mentioned previously, lack of wireless equipment on ships.
4. Seeming slowness of shipping companies to realize the need for wireless or radio equipment.
5. Unreliable radio apparatus with transmission service suffering accordingly and delivery of weather messages uncertain.

It may be readily seen from the foregoing that the struggle to build up the Pacific vessel weather service to a point of real usefulness was a difficult task. Progress was very limited for the first 14 years.

[1] Presented before the meeting of the American Meteorological Society at Berkeley, Calif., June, 1929.